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AN ATTEMPT TO ESTIMATE RATES OF RETURN TO INVEST IN INFANT NUTRITION PROGRAMS

by

Marcelo Selowsky

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An Attempt to Estimate Rates of Return to Invest in Infant Nutrition Programs*

Marcelo Selowsky
Harvard University

To be presented at the International Conférence on Nutrition, National Development and Planning, Massachusetts Institute of Technology (October 19-21, 1971).

*This is part of a research project my colleague, Lance Taylor, and I are undertaking on the economics of malnutrition. I am indebted to him and Mrs. Vera Kardonsky for valuable comments and suggestions. I am also extremely grateful to Dr. Oscar Undurraga and Mrs. Kardonsky for allowing me to use the raw data from their study (9). This research was begun while I was a member of the Institute of Economics, Catholic University of Chile.

A. INTRODUCTION

The need of quantifying the economic impact of malnutrition is perhaps one of the most important messages in Dr. Barg's paper. His reasons are overwhelmingly realistic. Policy makers, even though they are concerned by the ethical implications of malnutrition (or the "welfare position" as called by Dr. Barg), face the pressure for scarce investments resources from all agencies and economic sectors in the process of allocating those resources. For many of these sectors clear figures on the economic impact of investment can be derived. For this reason it is very probable that the amount of resources that currently are devoted to fight malnutrition, mainly determined by these ethical considerations, could increase if somehow comparable figures on its economic impact could be estimated. To the extent that this hypothesis is true some effort should be spent in quantifying this impact. This is the purpose of this paper.

To integrate malnutrition in an economic model we need for a framework or set of hypotheses which can be summarized in parameters whose magnitude can be tested. Most of the time such a framework requires a simplification of the problem. We will have to do this again here. The scope of analysis we will use will cover the following aspects:

(a) We are only interested in quantifying the economic impact of infant or early malnutrition, in other words malnutrition in preschool age. The empirical evidence suggests that the economic impact of infant malnutrition, especially in less developed countries, could be of importance. Symptoms of protein-calorie malnutrition in preschool children in less developed countries have been reported widely by the WHO reports and a variety of country-wide nutritional surveys. On the other hand, there is a growing evidence in the medical and psychological field that tends to show that early malnutrition, basically a deficit in the intake of proteins, could affect adversely the mental capability and subsequent learning ability of children.

(b) The economic impact to be studied will be the effect of early malnutrition on the future economic productivity of the individual as a member of the labor force. We will not cover other economic effects which can be of importance like the additional resources required by the health sector in fighting later disease and infection that could be induced by early malnutrition. The importance of the relationship between nutrition and infection has been discussed by Scrimshaw (12).

(c) The analysis will be essentially, as we economists call it, microeconomic. We will analyze the impact of early malnutrition on the individual without attempting to generalize this relationship to macroeconomic magnitudes. In other words, we will not attempt to answer other interesting but very ambitious questions like how much of the economic growth of a country can be explained by the resources devoted to better nutrition.

B. FRAMEWORK OF ANALYSIS

Ideally one would like to have a sample of individuals followed for a long period of time and for which data, since birth, on all variables affecting productivity was available. With a sufficient variability in the (early) nutrition variable (somehow defined) it would be possible to isolate the effect of this variable from the effect of other variables affecting productivity.

However, as long as this longitudinal data is not available--and probably it will not be for a long time--it is necessay to use cross-section data to obtain a replica of the longitudinal data. Therefore we need a framework that organizes cross-section data in such a way we could somehow test the probable impact of early malnutrition on the future producitivity of an individual. Let us assume this framework can be summarized in the following set of relationships:

(1) $P_j = \alpha[IQ_j, E, j]$

(2) $E = \beta[IQ_p .....]$

(3) $IQ_j = \rho[IQ_p ...]$

(4) $IQ_p = \delta[N, F, G]$

Relation (1) states that the productivity of an individual at age j (P_j) is a function of an ability or IQ measure at that age (IQ_j), an index of the amount and quality of his education (E) and of his age. We require the hypothesis that there exist an IQ measure which is relatively independent of the level of education and age of an individual.

Relation (2) summarizes the hypothesis that the amount and quality of education an individual can absorb is a function, among other things, of his level of ability at the age he enters school. Let us assume this ability index can be also summarized in an IQ measure at preschool age (IQ_p). Expression (3) states that the IQ measure at age j depends, among other variables, on the level of IQ at preschool age.

Finally, equation (4) advances the hypothesis that the level of IQ at preschool age (or at the age the child enters school) is a function of an index of the nutritional status of the child between birth and the age he enters school (N), of an index of the quality of family environment (F) and of heredity or what can be called genetic endowment (G).

The impact of a child's nutritional status on his future productivity can be determined by differentiating P_j with respect to N:

$$(5) \quad \frac{\partial P_j}{\partial N} = \frac{\partial P_j}{\partial IQ_j} \frac{\partial IQ_j}{\partial IQ_p} \frac{\partial IQ_p}{\partial N} + \frac{\partial P_j}{\partial E} \frac{\partial E}{\partial IQ_p} \frac{\partial IQ_p}{\partial N}$$

$$= \left(\frac{\partial P_j}{\partial IQ_j} \frac{\partial IQ_j}{\partial IQ_p} + \frac{\partial P_j}{\partial E} \frac{\partial E}{\partial IQ_p}\right) \frac{\partial IQ_p}{\partial N}$$

Expression (5) shows that under this set of hypothesis early malnutrition, through affecting preschool IQ, affects future productivity in two different ways: directly, as long as there is a relationship between different measures of IQ through time and second, by affecting the level of schooling (quantitatively and qualitatively) the individual can reach and to the extent that schooling influences his level of productivity.

The purpose of this paper is to estimate the magnitude of $\frac{\partial IQ_p}{\partial N}$ or the impact of the nutrition variable on preschool IQ (holding constant the effect of the other variables affecting preschool IQ) and of $\frac{\partial p_j}{\partial IQ_j}$ or the impact of an adult IQ on his productivity (holding constant the effect of the other variables affecting productivity). As can be seen we fall short of estimating the other terms needed to evaluate expression (5). To estimate the direct effect of early malnutrition on productivity we also need $\frac{\partial IQ_j}{\partial IQ_p}$ or the net relationship between different measures of IQ through time. This is precisely the relationship whose estimation requires longitudinal data about which we talked earlier. On the other hand, in order to quantify the effect of early malnutrition via education we need to estimate $\frac{\partial p_i}{\partial E}$ and $\frac{\partial E}{\partial IQ_p}$. For the first term some information is available from other studies; however we have, up to now, been unable to estimate the second term or the impact of preschool IQ on schooling. It ought to have first priority in any future research.

C. ESTIMATING THE EFFECT OF INFANT MALNUTRITION ON PRESCHOOL IQ

Using statistical techniques different studies have shown that, in a variety of mental tests, malnourished children have a lower performance than matching groups that could be considered as controls [Stoch and Smythe (13), Craviotto and Robles (5), Craviotto and De Licardie(6), Monckeberg (10)].

The main concern is to what extent those controls have allowed the isolation of the effect of malnutrition from other environmental handicaps which almost always are also present in the families of malnourished children.

A recent research conducted in Chile by Drs. Kardonsky, Undurraga, Alvarado, Seguir and Manterola (9) has come up with a remarkable result: preliminary results have, as usual, shown significant differences between strongly malnourished children (all of them reaching malnutriton of degree three during the first fifteen months of life) and well nourished controls, but what is most important, they have also found a significant rank correlation between mental tests and "early" weight indices <u>within</u> the group of malnourished children. The importance of this result in the effort of isolating the effect of malnutrition is that very probably the "intra" homogeneity of the group of malnourished children (with respect to environmental variables) is much stronger than in relation to any matching group of well nourished controls. The above researchers have kindly provided the raw data of their study in order expression (5) could be quantified by using regression analysis. We now describe the characteristics of the data.

A group of thirty-three children from a very low income neighborhood of the northern section of the city of Santiago and who experienced strong protein-caloric malnutrition during their first year of life were hospitalized and followed in a longitudinal study. All of them reached, during their first year of life, a weight deficit approximately equal to 40% of their normal weight.[1/] However, the distribution of their birth weight was considered as normal by international standards and they were also free of any birth abnormality or any later disease.

At the same time eleven "normal" children from the same neighborhood were selected as controls. However, we were able to trace the exact weight history for only seven of them. Between ages three and three and a half all of these children were given a Terman-Merril Intelligenct Test. For all of these children monthly weight data is available from birth. Data on the mothers' Intelligence Test (Wechsler Test) and mothers' education (years of schooling) are available for the normal children but only for twenty-eight of the thirty-three malnourished children. Four sample groups can therefore be distinguished according to the availability of data:

Group I (n=33) - group of malnourished children

Group II (n=40) - total sample (malnourished + normal children)

Group III (n=28) - malnourished children with family background data

Group IV (n=35) - total number of children with family background data

Table I summarizes the means and standard deviations of

[1/] The norm of comparison is the IOWA standard obtained by Jackson and Kelly for the United States (8).

Table I
Means and Standard Deviations (in parenthesis)
of the Variables Used

	malnourished children	normal children
Terman-Merril Children Test	72.8(11.4)	97.1(9.9)
S_1 = average (relative) monthly weight first semester	62.0(7.1)	104.6(15.8)
S_2 = average (relative) monthly weight second semester	58.8(10.5)	104.1(15.8)
S_3 = average (relative) monthly weight third semester	73.9(10.5)	102.2(11.0)
W_{18} = average (relative) monthly weight first 18 months	65.0(6.8)	102.6(13.2)
W_{30} = average (relative) monthly weight first 30 months	72.6(7.3)	103.9(13.5)
mothers' years of schooling	3.7(2.3)	3.8(2.1)
mothers' Intelligence Test	70.9(14.7)	70.7(13.4)

Note: The relative weight is relative to the IOWA standard and expressed as a percentage.

the main variables used. The control group appears to be normal according to weight and IQ test. However, the mean figure for mothers' IQ and mothers' years of schooling are almost the same for both groups.

Table II shows the results of regressing the Terman-Merril test to the different weight figures. The first attempt was to test the hypothesis that the earlier the age the child is malnourished the stronger the impact on his mental development. Different multiple regressions with lagged quarterly weight data gave quite unstable and insignificant coefficient given the high degree of multi-colinearity at this level of disaggregation of the weight data. First differences did not improve the result.

By using semesters it turned out that the 3rd semester coefficient was significant and quite stable. This is shown in regressions 1 and 2. By using the average monthly weight figure in the first eighteen and thirty months a similar coefficient was obtained, also quite stable with respect to the sample used (regressions 3 and 4).

What is interesting in these regressions is the significance of the weight data in spite of the extremely low variance of the variables in the group of malnourished children (see Table I). On the other hand, all regressions show a remarkable stability of the coefficients of S_3, W_{18} and W_{30} independently of using the group of malnourished children or a pool of mal-

TABLE II

Dependent Variable - Terman-Merril Childrens' Test

No. Regr.	Indep. Variab.	Group I n=33 malnourished children	Group II n=40 pool	Group III n=28 malnourished children	Group IV n=35 pool
	intercept	41.32(1.99)	28.79(2.75)	43.65(1.75)	28.92(2.38)
	S_1	-0.14(-0.56)	-0.02(-0.14)	-0.14(-0.51)	-0.03(-0.18)
	S_2	0.05(0.23)	0.14(0.76)	0.06(0.23)	0.17(0.71)
1	S_3	0.51(2.45)	0.51(2.37)	0.46(1.65)	0.49(1.73)
		R^2 = 0.25	R^2 = 0.48	R^2 = 0.17	R^2 = 0.48
		$\bar{R}^2$ = 0.17	$\bar{R}^2$ = 0.43	$\bar{R}^2$ = 0.07	$\bar{R}^2$ = 0.43
		F = 3.24	F = 11.13	F = 1.68	F = 9.83
	intercept	33.36(2.63)	25.13(2.76)	35.18(2.18)	23.83(2.44)
2	S_3	0.53(3.14)	0.66(5.81)	0.50(2.26)	0.67(5.50)
		R^2 = 0.24	R^2 = 0.47	R^2 = 0.16	R^2 = 0.47
		F = 9.89	F = 33.78	F = 5.08	F = 30.22

Note: Figures in parentheses represent the t ratio of the coefficient.

TABLE II (Cont.)

No. Regr.	Indep. Variab.	Group I n=33 malnourished children	Group II n=40 pool	Group III n=28 malnourished children	Group IV n=35 pool
3	intercept	35.11(1.91)	37.43(4.78)	42.13(1.92)	36.53(4.47)
	W_{18}	0.58(2.06)	0.55(5.19)	0.56(1.33)	0.55(5.03)
		R^2 = 0.12	R^2 = 0.41	R^2 = 0.08	R^2 = 0.43
		F = 4.26	F = 26.98	F = 1.78	F = 25.35
4	intercept	25.35(1.34)	26.13(2.61)	32.98(1.43)	25.94(2.47)
	W_{30}	0.65(2.53)	0.65(5.18)	0.54(1.69)	0.65(4.90)
		R^2 = 0.17	R^2 = 0.41	R^2 = 0.10	R^2 = 0.42
		F = 6.39	F = 26.82	F = 2.87	F = 24.00
5	intercept			9.33(0.45)	
	S_3			0.49(2.32)	
	SI			0.46(1.94)	
				R^2 = 0.27	
				F = 4.69	
6	intercept			1.03(0.03)	
	W_{18}			0.59(1.83)	
	SI			0.56(2.24)	
				R^2 = 0.22	
				F = 3.53	
7	intercept			-6.13(-0.22)	
	W_{30}			0.64(2.14)	
	SI			0.56(2.27)	
				R^2 = 0.25	
				F = 4.24	

Note: Figures in parentheses represent the t ratio of the coefficient.

nourished and normal children. The coefficients of 0.50 to 0.65 implies that a gain of 10 percentage points in that particular relative weight variable generates an increase in IQ (measured by that particular test and at that particular age) of 5 to 6.5 points. The stability of these coefficients across samples suggests that this impact may be similar in the range of strong as well as intermediate ranges of malnutrition as measured by weight figures.[1]

If heredity has a role in explaining childrens' intelligence scores, mothers' IQ could be used as a proxy for the ability endowment at birth. It also could be used, together with mothers' year of schooling, as a proxy for family environment affecting mental growth. However, we found these two variables to be insignificant in the explanation of IQ. What turned out to be significant was a composite socio-economic index (SI) provided to us by Dr. Kardonsky and her collaborators from the Institute of Psychology at the University of Chile. The interesting feature of this index is that it seems a very good proxy for wealth and therefore can provide a better proxy for long run overall environment than simply family income. It also provides a good index of general health and sanitary facili-

[1] It is necessary to point out that the norm used as a denominator for the weight figures (in this case the IOWA norm) does not affect the significance of the weight variable. It only changes the interpretation of the coefficient.

ties at home.

This index was based on the following ten characteristics of childrens' home:

- type of housing
- toilet facilities
- bathing facilities
- cooking facilities
- location of cooking facilities
- ownership or rental arrangement of the house
- elimination facilities
- water source
- lighting system
- per capita income

Each characteristic i had n_i possible sub-characteristics ordered by "quality." The maximum score (for the highest quality sub-characteristic) was common to all characteristics. Four per capita income brackets were defined, the highest bracket having also that maximum score.

Regressions 5, [illegible] and 7 show that between 22% and 27% of the variance in childrens' IQ can be explained by weight indices and the described socio-economic index (IS). On the other hand, the coefficient of weight does not appear to be very sensitive to the introduction of the socio-economic variable. This is important; it means that even the socio-economic index accounts for a fraction of the explained variance it does not change the impact of the nutrition variable on the IQ score.

Conclusions:

The results show that early weight figures appear to be significant in explaining the variance in childrens' IQ. The main characteristics of the results are the following:

(1) The early weight figure is significant even restricting the sample to the group of malnourished children; this result is important given the low variance in the weight figures within the sample of malnourished children and also the fact that this variable remained significant and stable even by holding constant a socio-economic index of the family.

(2) The magnitude (coefficient) of the impact of the weight variable on IQ is quite stable across sample groups. In other words, this magnitude is almost the same within the group of malnourished children and in a pool of malnourished and normal children.

(3) We have to accept the fact that we have identified variables that account for a relatively small fraction of the total variance in childrens' IQ. However, we are not interested in identifying all the relevant variables so we can predict IQ accurately. We are interested in identifying variables which can be operated by policy and whose quantitative effect can be important for the problem at hand. This is our next step: to determine how important could be the losses in childrens' IQ due to malnutrition in explaining their future productivity.

D. PRODUCTIVITY AND IQ IN ADULTS

Ideally we would like to have enough longitudinal data to estimate the net impact of preschool IQ on an individual's future productivity. As we mentioned earlier, as long as these data are not available we have to use cross-section data and make some assumption in order to link this information through time.

Following our earlier framework, the alternative we have chosen is to estimate the effect of some ability measures in adults on earnings and then attempt to relate these measures to preschool IQ deficits.

We asked the psychologists to provide us with an adult IQ test able to measure "as closely as possible" the same kind of capabilities that the Children's Terman Merril Test was measuring at three and a half years old. It was decided that a particular subset of the Wechsler-Bellevue test for adults could be appropriate.[1]

A group of thirty-one employed construction workers and a group of sixty unemployed workers were given the Wechsler-Bellevue Test. The construction industry in Chile can be considered quite competitive both in the product and factor mar-

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[1] The subtests used were general comprehension, similarities, picture completion, picture arrangement, object assembly and block design.

kets so we can assume the wages paid are a good proxy for marginal productivity. The sixty unemployed workers were sampled while they were looking for employment at SENDE, a Government Employment Agency; for this group the earnings figure of the last job was also computed. Table III summarizes the information for these two groups.*

Table III shows a substantial difference between the earnings of the actually employed construction workers and the last job earnings figure of the unemployed workers. It also shows a strong difference between the time of unemployment between the penultimate and last job. Construction workers performed consistently better in all subtests of the Wechsler-Bellevue Test and have a significant higher standardized IQ test (0.025<P).

Characteristics reflecting the environment they were raised in are quite similar for both groups: parents' years of schooling are almost the same; rough indices of per capita income of the family during their youth (age they began earning any income, number of brothers) also appear to be quite similar.

Given the above considerations it is tempting to attribute the difference in earnings between the two groups to some index of basic intelligence as measured by the Wechsler-Bellevue IQ Test. However, in order to obtain additional information on the effect of IQ on earnings, several regressions were run using the two samples separately and also a pool of the two

*I wish to thank Mrs. Marilu Figueroa and Mrs. M. Eugenia Pulido for their assistance in obtaining and processing the sample data.

Table III

Means and Standard Deviations (in parenthses) of Workers Data

	construction workers (n=31)	unemployed workers (n=60)
I (1) age	31.9(2.6)	28.2(5.4)
(2) years of schooling	4.6(2.4)	5.2(1.0)
(3) mother's years of schooling	2.8(2.6)	3.0(2.2)
(4) father's years of schooling	(n=20) 3.7	(n=40) 3.8
(5) no. brothers	5.4	5.1
(6) fraction of those who spend their childhood in the rural sector	.52	.57
(7) age they began earning any income	13.7(2.7)	13.6(2.4)
(8) months of unemployment between jobs	1.1(1.0)	2.3(2.1)
(9) monthly earnings last job (E^o 1970)	1320(440)	819(378)
II Components of the Wechsler-Bellevue IQ Test (raw scores)		
(1) general information	8.0(4.2)	7.2(3.7)
(2) general comprehension	10.4(4.2)	8.8(3.0)
(3) arithemetical reasoning	4.5(1.8)	4.1(1.7)
(4) digits forward and backward	7.8(1.8)	7.1(2.0)
(5) similarities	8.4(3.7)	7.6(4.0)
(6) picture completion	7.4(2.4)	6.9(2.8)
(7) picture arrangement	5.4(2.3)	5.0(3.8)
(8) object assembly	19.9(3.6)	15.0(3.9)
(9) block design	15.7(7.4)	14.0(9.0)
(10) digit symbol	24.3(8.2)	22.5(10.3)
III Standardized IQ Test (includes 2, 5, 6, 7, 8, 9, & 10)	87.3(14.9)	77.6(17.8)

Table IV
Regressions from Workers Data
dependent variable = log earnings

reg. no.	indep. variable	construction workers	unemployed workers	pool
1	intercept	4.12(4.82)	3.08(3.55)	2.65(3.86)
	log age	0.87(3.52)	1.06(4.06)	1.23(6.03)
		R^2 = 0.30	R^2 = 0.22	R^2 = 0.29
2	intercept	3.23(2.28)	2.82(2.78)	1.92(2.16)
	log IQ	0.87(2.75)	0.87(3.74)	1.11(5.49)
		R^2 = 0.21	R^2 = 0.19	R^2 = 0.25
3	intercept	1.68(1.25)	1.36(1.26)	0.34(0.38)
	log age	0.74(3.08)	0.79(2.92)	0.92(4.48)
	log IQ	0.65(2.26)	0.60(2.52)	0.76(3.83)
		R^2 = 0.41	R^2 = 0.30	R^2 = 0.39

Note: Figures in parentheses show the t ratio of the coefficient.

groups.

Table IV summarizes the best regressions. The elasticities of earnings with respect to age and IQ are significant and stable. They suggest that a 10% change in IQ, as measured by our test, is associated with a 6 - 6.5% increase in earnings. Parents' and workers' years of schooling were not significant; this last result can be explained by both the low level and low variance in the workers' schooling variable.

E. EARLY MALNUTRITION AND FUTURE PRODUCTIVITY: A COST BENEFIT ANALYSIS

The next task is how to integrate the results of the last two sections so we can say something about the effects of early malnutrition on future productivity.

Before attempting this, it is useful to describe what Chilean psychologists thought about the future development of the thirty-three malnourished children. According to them, the absolute level of retardation, as shown by the resúlts of the tests, observed in these children call for only one solution: special schooling. With this level of preschool IQ, the children are not able to profit from the regular schooling system. Even more, participation in the regular schooling system would imply furthe retardation in the future. If further retardation means zero future productivity (or negative?) the effect of early nutritional programs might well be the transformation of an individual fro a non-productive to a productive agent. However, given that these children are probably an extreme case in the spectrum of early malnutrition and given our purpose to be rather conservative in estimating the costs of malnutrition we will not take this point of view.

The problem we face is how to predict an adult's IQ with an IQ measured at 3 - 4 years; in other words, we need an estimate of $\frac{\partial IQ_j}{\partial IQ_p}$. Psychologists have been concerned with this problem for a long time and there is an extensive literature on the subject [Bloom (3)]. Empirical evidence of this type is extremely scarce and we have found only one type of study that provides an appropriate longitudinal serie. This is the research by Bayley (2) based on the Berkeley Growth Study children.

The Berkeley Growth Study analyzed the IQ performance of sixty-one children of high income homes from birth to eighteen years. Intelligence measures at age two had a correlation (R) of .51 with intelligence measured at age seventeen. By age four, the correlation with the measurement at age seventeen increased to .71 and by age eleven it increased to .92.

In Bayley's longitudinal study different IQ tests were used at different ages. However the same type of test (Stanford-Binet) was given at six and seventeen years old. The score of the test was almost the same.

We do not think we can get out more from those experiences for purposes of our projections. If the IQ of the Berkeley children remained constant in spite of a rich environment after six years, can we expect the scores of the thirty-three malnourished children to improve given their future environment? We think we are being conservative by assuming that the IQ of these malnourished children will not change through time.

By assuming that the future IQ of the malnourished children will remain at 72.8 (see Table I) we could estimate the benefits of an early nutrition program aimed to bring their weight figure up to normality. From Table I we can see that their relative weight was between .65 and .74; by rising this figure by 30 percentage points we would expect, given the preschool IQ coefficient with respect to weight ($\approx$.60), their preschool IQ would go up to .908. Notice that this figure is still smaller than the average IQ figure of .971 of the "normal" children of the same neighborhood (Table I).

However, in order to understate the benefits, we will assume that the effect of a normal weight figure will be to increase their adult IQ to only .873, the average figure of the construction workers sampled.

Figure I shows the annual earnings profile of individuals with IQs equal to .728 and .87 evaluated with the three earnings equations of Table IV, where E_1, E_2 and E_3 are the earnings equations of the construction workers, unemployed workers and the pool of them, respectively. They include employer's contribution to the social security system, part of the marginal productivity of labor, which amounts to 30% of the net wage. By assuming the children enter the labor force at age fifteen

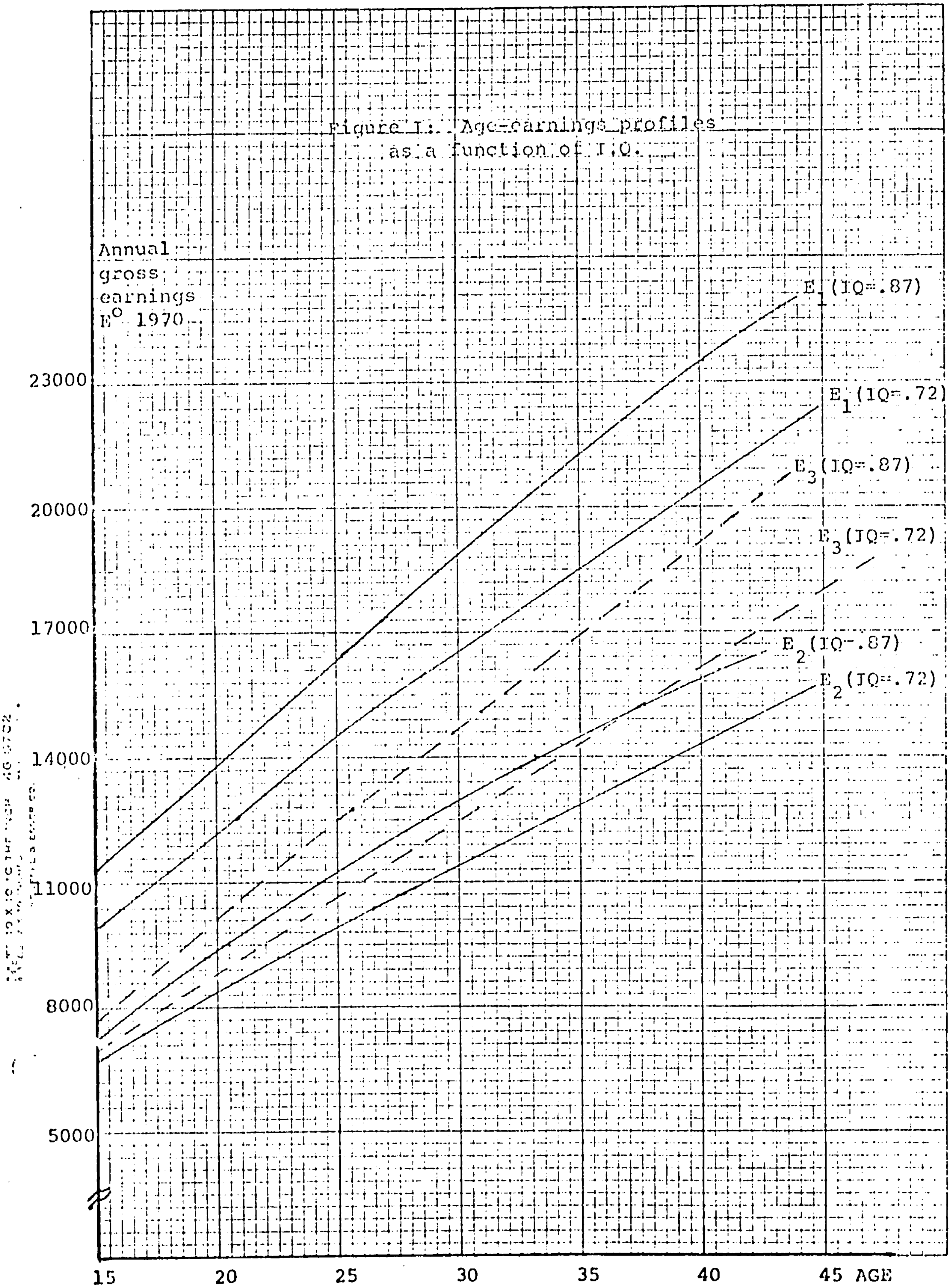

Figure I: Age-earnings profiles as a function of I.Q.

and that the relevant discount rate is 10%, the present value of the gains in gross earnings at age two are the following.[1/][2/]

E_1	E^o	6080	\$405
E_2	E^o	3842	\$256
E_3	E^o	5396	\$360

If we think these gains in earnings can be generated by a supplementary protein rich food program during the first two years of life, the above figure will represent the shadow price of such a program.

We have attempted to make a rough estimate of such a program. During the first two years of life the main source of "high quality" protein is milk. The daily requirements are roughly .6 liters during the first year (this is the average figure; the requirements change every month) and half a liter the second year. This amounts to 18 liters per month the first year and 15 liters per month the second year. We will define our program as one providing 20 liters per month per child during the first two years of life.

Chile is a net importer of (powdered) milk, the main source of its imports being Europe. The CIF price of these imports have fluctuated widely in the last three years according to the changes in the price support policies of the source country. From 1968 to 1970 the CIF price per ton of a

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[1/] We have used an exchange rate of E^o15 per dollar for 1970. See Bacha, E. and L. Taylor (1).

[2/] By not adjusting the earnings profiles by the differential probability of being unemployed through time we are understating the benefits of a higher IQ.

12% powdered milk went up from $160 to $500.[1] It is expected the future price will go up even further. We have taken the producer's price in the U.S. and in Europe as the upper estimate of the future CIF price of powdered milk. This price ranges from 7 cents to 10 cents per liter of 3.8% fat milk, a much higher in fat content type of milk. We will use $1000 per ton as the upper limit of the future CIF price.[2]

Tables V and VI present the net present value (per child) and the rates of return to this program. At a 10% discount rate the net present value of the program (per child, and at age two) ranges from $205.6 to $379.8, according to the earnings equation used and the international price of milk. A 100,000 children program would have an accumulated cost between 2.5 and 5 million dollars, a present value between 25 and 40 million dollars, and a net present value ranging from 20 to 38 million dollars. The estimated rates of return range from 19% to 25%, mainly a function of the projected CIF price of milk.

Rates of Return Comparisons

The estimated rates of return have to be considered as rough first approximations. However it is important to analyze if there are some biases that would tend to put these figures as maximum or minimum estimates. We now consider some of those

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[1] A ton of a 12% powdered milk is produced and converted into approximately 10,000 liters of fluid milk with 1.3% fat.

[2] From Chile's point of view what matters is the CIF price, irrespective if this price reflects or not the resource cost of producing milk in other countries. If wewere to evaluate this project from a world point of view, the resource cost of producing milk will be the relevant figure.

Table V
Net Present Value (per child) at age 2 of a 2-year Free Milk Program as a Function of the CIF Price of Powdered Milk (10% Discount Rate) in Dollars

earnings equations used to evaluate changes in IQ	CIF price $500 per ton or 5¢ per liter			CIF price $1000 per ton or 10¢ per liter		
	Cost 1/	PV 2/	NPV	Cost 1/	PV 2/	NPV
E_1 (construction workers)	25.2	405	379.8	50.4	405	354.6
E_2 (unemployed workers)	25.2	256	230.8	50.4	256	205.6
E_3 (pool)	25.2	360	334.8	50.4	360	309.6

1/ represents the accumulated cost at the second year.

2/ from page 22.

Table VI
Rates of Return of a 2-year Free Milk Program as a Function of the International Price of Powdered Milk

earning equation used to evaluate changes in IQ	international price per ton powdered milk U.S. $1000	U.S. $500
E_1 (construction workers)	21%	25%
E_2 (unemployed workers)	19%	22%
E_3 (pool)	20%	24%

probable biases.

As can be seen from expression (5) we have left out the second term or the "education effect" of that expression. It is very possible that a higher preschool IQ, induced by a better infant nutrition, will allow the individual to achieve a better and higher level of schooling. There is some evidence on this hypothesis. Using the Berkeley Growth Study Conlisk found a significant coefficient of preschool IQ in the explanation of years of schooling holding constant parents' income and parents' education (4). To the extent that learning at school is a function of early nutrition and as long as this learning affects future productivity we are understating the total benefits of an infant nutrition program.[1/]

It seems there is enough evidence that shows that infectious disease is likely to be less severe and less frequent in well nourished individuals [Scrimshaw (12)]. Malnutrition not only affects adversely the defense mechanism of the individual but also favors secondary infections and increases the convalescence period. To the extent that medical resources are used by infectious diseases induced by malnutrition, savings in those resources should also be attributed to nutrition programs.

By not including the above benefits the estimated rates of return are an underestimate of the true figures. However

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[1/] Not all of the benefits of the "education effect" can be attributed to a nutrition program if additional resources in the educational sector are also required.

there are some biases on the cost side of the program, as we defined it earlier, that probably have tended to overstate the rates of return. The most important one is that the implementation of such a free milk program can have important administrative and distribution costs which should be added to the CIF price of milk. This is particularly true when the success of such a program depends heavily on teaching mothers some minimal practices of hygiene in child feeding.

As can be seen in the following table the estimated rates of return appear to be higher than comparable figures for investment in physical capital and education, another source of human capital formation. If we accept these figures we have to agree

Chile: Rates of Return to [illegible] in

Physical Capital	Schooling	Infant Nutrition
15%	Primary 17% Secondary 15%	19%-25%

Sources: See (7) and (11)

that Chile's long run rate of economic growth will increase by devoting a higher fraction of its total investment to fight infant malnutrition.

F. FINAL COMMENTS

If infant nutrition has an effect on an individual's future economic productivity it must be considered as one of the sources of human capital formation. However infant nutrition has some major differences with other types of investment in human capital, i.e., formal schooling, on the job training, etc.

First, infant malnutrition can hardly be substituted by later types of investment in human capital. On the job training is a much better substitute for deficit in years of schooling than deficits in preschool IQ.

Second, later types of investment in human capital can, for policy purposes, be affected by an improvement in capital markets (i.e., loans for high school or college education). This is hardly true for earlier types of investment in human capital. For these investments, perfect capital markets are not a substitute for income redistribution, the main determinant of early investment in human capital.

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